

## Force Feedback in Video Games

For years, game developers have been pushing the envelope, first in terms of graphics and then in artificial intelligence and audio. Having already pushed the boundaries in those areas, game developers are now looking for other ways to engage game players and create a truly immersive experience. One such area that has yet to be fully exploited is tactile sensation.

### Tactile sensations

Tactile sensations have historically been hard to convey artificially. The range of possible sensations is much larger than other senses since the skin and the body itself have various sensory organs for different stimuli, such as dry/wet, hot/cold, hard/soft, pressure, position, vibration, and so on. Today, most feedback devices on the market are engineered to reproduce the mechanical sensations (force, position, and vibration). Some feedback devices target only the hands, such as rumble pads or force feedback joysticks. Others target the body's proprioception, which is the sense that allows individuals to know where their body is in relation to their surroundings. Examples of these types of devices are the D-BOX chair or the various arcade props, including bikes, race cars, and so on.

To date, these devices have been used in a game to do any or all of the following:

- Give the player more information about the state of his character or environment. For example:
  - o Health status
  - o Hitting an unseen object
  - o Hitting the curb in a racing game
  - o Rumble due to the destruction of a nearby building
- Add realism by imitating the real feedback of an object. For example:
  - o Engine revolutions in a car
  - o Bumps in the road
  - o Attitude of an airplane (D-BOX)
  - o Feeling of acceleration or deceleration (D-BOX)
  - o Explosions in a war game
  - o Gun shots
- Surprise the player by giving him a jolt at unexpected times.
- Give the player feedback on an accomplished task. For example:
  - o Catching the ball in a football game
  - o Hooking a fish (WiiPlay)

### Relationship with Sound and Video

In real life, the brain is used to receive multiple stimuli at the same time for the same event. For example, hitting a ball with a bat will produce a sound and a vibration, on top of the obvious visual cues. Reproducing this association between multiple types of senses is important for better immersion. If the game player does not feel the same thing as in real life, he may notice (probably unconsciously) that something is missing and the overall experience may feel artificial. Of course, gamers are used to the missing details but adding tactile sensations to the existing audio and video cues will improve the overall experience of the game. Obviously, synchronising all the cues together is very important.

### Haptic Device Mechanisms

The word "haptic" comes from a Greek word that means "pertaining to the sense of touch". Haptic devices use technology that engages the user via the sense of touch by applying forces, vibrations, and/or motions to the user. In video games, several different types of haptic devices support a type of force feedback, including:

- Gamepads
- Joysticks
- Steering wheels & pedals
- Light guns
- D-BOX chair

Some of these devices, like gamepads, are low cost, use a very simple mechanism, and have been around for many years, whereas others, like the D-BOX chair, are more expensive, use a sophisticated mechanism, and are just becoming known in the gaming marketplace.

## Gamepads

The most common type of tactile feedback in video games is the rumble in the various versions of game pads (controllers). The basic mechanism used in game pads is a simple electric motor rotating a mis-aligned mass. Some game controllers have 2 motors, usually with different masses and rotating speeds, to provide a wider range of sensations. The amplitude of the movement provided by one motor is directly proportional to the mass being moved; the higher the mass, the higher the amplitude. This also usually translates into a lower frequency of vibration. The starting position of the mass, whether it be up or down, will also affect the vibration.

The speed of rotation also has an effect on the perceived intensity of the vibration. This effect is non-linear, especially with larger masses. At low speeds, the player will feel that the game pad is “jerking” instead of vibrating. As the speed increases, there will be a cross-over point where the “jerking” motion becomes more of a vibration. From this point on, the higher the speed, the higher is the perceived intensity.

The speed is the only parameter that can be controlled on game controllers. For some, it will be a gradient (0-65536 for Xbox, 0-255 for large PS3 motor), yet for others it will be a simple on-off switch (Wii and small PS3 motor). When changing the speed, remember that the electric motor has inertia. That means that it may take some time before it reaches the desired speed or stops. In some cases, this lag may be important enough to take into account when developing the feedback for a game.

It is important to understand that each controller model will react slightly differently to the same input. Usually, the wireless versions of the controllers will have less electrical power available, therefore the motors will induce less energetic vibrations. So when designing feedback for the controllers, a compromise must be taken between the different capabilities of each model, even when used on the same platform.

## D-BOX Gaming Chair

The D-BOX gaming chair offers a much broader range of sensations to the game player. The actuators can reproduce positions, slow movements, and a continuous range of vibration frequencies from 0 to 100 Hz. The amplitude of movement is 35 millimetres.

Its linear actuators can be thought of as speakers with a very good frequency response in the low frequencies. With this in mind, designers of feedback can apply the same concepts used to create audio. It is possible to mix signals together to make a composite stimulus. For example, a car engine vibration could be mixed with a bumpy road waveform. A banking movement to the left could also be added to simulate the inertia of the driver while turning right. The overall result would feel like a car turning right on a bumpy road.

The similarity with audio also means that the same care must be taken with the signal. Problems occurring in audio can occur with the DBOX chair:

- **Clipping.** The addition of multiple signals during the mixing exceeds the digital limits of the signal or the physical limits of the chair. Using peak limiters, compressors and expander effects can attenuate this problem. But careful design and proper signal pre-processing are better tools to avoid this. Of course, due to the interactive nature of a game, not all situations can be anticipated.
- **Clicks or kicks.** As in audio, signals that don't end on the neutral level (0) could cause some kicks (the chair literally kicks the game player) when it abruptly returns to the neutral level. Note that this can only happen when playing two waveforms back to back that don't end or start at 0. This can be avoided by designing waveforms that start and end at 0.
- **Interference and beating.** Two waveforms with frequency content too close to each other could create constructive or destructive interference. Due to the limited spectrum of operation (0-100Hz) it is likely that two such waveforms are played at some point. This is especially important for sources that play for a long time where this interference can be noticeable. For short sources, this problem is less important or even non-existent.

On top of the common audio problems that apply to the D-BOX signals, there are some physical limitations related to the mechanism of the chair. While the actuators are able to move fast, their acceleration is limited to 1G (9.8 meters/s<sup>2</sup>). If it were possible to accelerate faster, the actuators would retract faster than the chair is falling, which would make it airborne for a fraction of a second, followed by a hard shock that would be noisy, uncomfortable, and possibly damaging to the equipment. This has implications over the frequency response of the actuators. The frequency response follows the shape of a second order Butterworth filter with a corner frequency of 6.5 Hz. Signal limiting may be required in order to comply. This, however, may introduce some distortion. So, if the resulting movement of the chair is distorted, it probably means that either there is too much amplitude in the signal or the signal transient is too abrupt.

## Methods for Supporting Force Feedback in Games

Traditionally, the process of adding rumble support to a game (and more generally any force feedback) involved a lot of trial and error. This meant that a programmer and a designer would sit together and change bits of code, recompile, and then try the result in-game.

Although this process was effective, it was slow, labour intensive, and each iteration required the help of a programmer, making it difficult to fine-tune and tweak the force feedback in your game.

In an attempt to streamline the creation of force feedback, new, more efficient methods have begun to emerge, including:

- Using audio signals as a feedback generator.
- Generating pure feedback signals using various sources.

These new methods are beginning to appear in established audio pipeline applications, such as Wwise. These types of applications are designer-centric, and literally remove the necessity for programmer intervention for inherently creative processes. Designers can experiment and simulate a variety of different scenarios within the authoring application and in-game without requiring the help of a programmer.

By integrating these new methods into applications like Wwise, feedback can be created alongside game audio for all platforms simultaneously. Since the differences in each platform are abstracted from the designer and programmer, once the feedback is created for one platform, it works for all platforms.

## Using Audio Signals as a Feedback Generator

In real life, most sounds are created by the interaction of two objects together. This usually creates shockwaves (in the case of impacts) and vibrations that travel through both objects. The response of the objects to the shockwave creates additional sound. When these events are recorded, the original shockwave and vibration will sometimes be recorded within the low-frequency spectrum of the audio signal, even if they are a bit distorted. The key is to extract this portion of the audio signal to generate feedback from sound.

In an application such as Wwise, it is possible to extract these low-frequency components of a sound and use them as the signal to drive feedback devices. Obviously, the precision of the result will depend on how much of the low-frequency spectrum of the original event was kept in the recording and how much environmental distortion (reverb, echo, etc) exists.

In most cases, this method can produce good results for explosions, impacts and even some rumbling sounds (volcanoes, earthquakes...) as long as there is not too much echo in the audio file.

To effectively manage the audio and feedback portions of the signal, the audio signal is split into two distinct signals right before the sound is sent to the audio mixing bus. By doing so, the two signals can be managed separately. This ensures that the separate motion signal is not affected by any audio-specific properties and effects applied on the audio busses.

Using audio as a source for feedback has some advantages:

- Both signals will always be synchronized
- You don't need separate objects, sources and events
- There is no additional memory used for the feedback data

It also has some disadvantages:

- Extra CPU is needed to extract the low-frequencies
- The result might not be what's wanted even after tweaking
- No independent control over the signal (slave to the audio)

The following illustration demonstrates how Wwise, for example, generates and manages the different audio and feedback signals. (Figure 1 Audio and Motion pipelines)

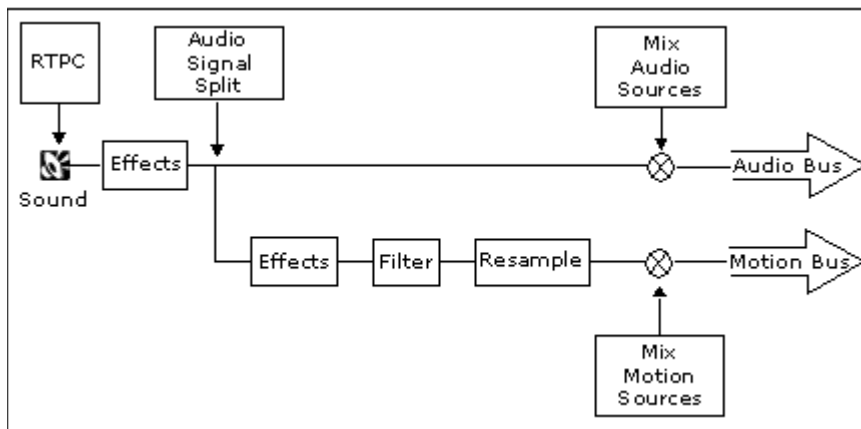


Figure 1 Audio and Motion pipelines

## Generating Pure Feedback Sources

In some cases, extracting the low-frequency signal from a sound will not create the desired result and in other cases, the audio signal will not even be related to the expected tactile sensation. To handle these cases, the feedback signal will need to be created from scratch. This can be achieved using any number of methods, including the following:

- By using a separate wave file to generate the signal.
- By using a signal generator where feedback curves are created manually in a graph view, such as the Motion Generator in Wwise.
- By using a signal generator that automatically generates a waveform, such as a tone generator.

The method used will ultimately depend on the output device and the type of feedback you are trying to create.

There are important advantages of using pure feedback sources:

- Small amounts of memory and CPU are used because the sample rate is very low.
- There is independent control over the feedback signal.
- Independent effects, such as Expanders and Compressors, can be applied to the feedback signal.

## Mixing Feedback Sources

In audio, we can mix several inputs together and still be able to distinguish the individual sources and thus, get information about them. This is especially true if the sources are located in almost separate bands in the audio spectrum. However, it is not so with tactile sensations. This sense can be rapidly overloaded, mainly because of the narrow spectrum of operation.

This is especially important with game controllers. While you can control each motor separately, having two unrelated sources playing may actually destroy the meaning of the feedback. The large motor, at full speed, can drown out the vibrations of the small motor. It is still possible to mix unrelated sources and have an acceptable result if one of the sources is very short. In this case, the short vibration will punch through the longer source and will still inform the game player about the event that just happened.

With the D-BOX chair, the range of possibilities is greater so the problem of mixing sources is lessened. The perceived sensations can be divided roughly into three parts:

- Movements (components below 5 Hz)
- Large vibrations (5-20Hz)
- High vibrations (20-100 Hz)

Mixing separate sources that fall into different categories will usually give the expected result, as long as no clipping occurs. Of course, this separation between sensations is not exact, which means that in some situations the mixed sources will produce the expected result and in others it won't.

Due to the interactive nature of games, it can be difficult to control the number of feedback sources playing at any one time. Many tools do exist to help you reduce the impact of these problems. For example, in Wwise, instance limits, peak limiters, and ducking busses can be used to reduce a potential cacophony of stimuli into something more understandable for the game player. As can be the case with other types of media, less is often more when dealing with tactile sensations.

## **Multiplayer Support**

Since many console games have a multiplayer mode, it is important that the force feedback design takes this into account. Each player is at a different point in the game so the feedback felt through each controller should match their particular gaming experience.

There are many different ways of dealing with multiple players. In Wwise, for example, feedback is generally treated the same as audio. Like audio, game objects emit feedback signals which are then received by one or more “active” listeners. Each listener represents a different player in the game and therefore is associated with a different game controller. When a feedback signal is emitted by a game object, the situation in game will determine which listeners become “active”, allowing only these listeners to receive that particular feedback signal.

**Note:** The D-BOX chair doesn't support a multi-player setup.

## **Conclusion**

Competition in the gaming world is fierce and game developers are always looking for ways to separate themselves from the pack. It is becoming clear that tactile sensations and force feedback are a means to this goal as they bring the gameplay experience to the next level.

Until now, game developers were limited by unsophisticated haptic devices and hindered by a cumbersome development process, which meant that the integration of force feedback was given little time at the end of development cycle.

Times are changing, however, and with the advent of sophisticated haptic devices like the D-Box chair and applications like Wwise Motion, force feedback should no longer be seen as a “nice-to-have”, but a “must-have”. With Wwise, designers are able to prototype tactile feedback quickly and easily for a variety of haptic devices at any stage of the development cycle. Synchronization with audio is easy since both signals are processed in the same compact engine. All the tools audio designers use to create interactive audio environments are now available to create tactile sensations that will help to further immerse the player in the game world.

Video games can only benefit from the continued development of haptic devices and the integration of force feedback. It is time to jump onboard as the goal of full immersion in the game world depends on it!